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Department of Meteorology



Scientific Report No. 2

# INSTALLATION AND CALIBRATION OF INFRARED SPECTROMETER

by

Ralph G. Eldridge

Contract No. AF19(122)-245

MEASUREMENT OF DROP SIZE DISTRIBUTION AND LIQUID

WATER CONTENT IN NATURAL CLOUDS

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D. P. Keily
Instrument Laboratory

July 1, 1952

# ABSTRACT

Modification of a Perkin-Elmer Infrared Spectrometer into a double beam system for measurement of transmission in water clouds is described. A cloud chamber for laboratory testing of the spectrometer is also described.

TABLE OF CONTENTS

# INSTALLATION AND CALIBRATION OF THE INFRARED SPECTROMETER

by

Ralph G. Eldridge

## I. General Description of Apparatus

The Infrared Monochromator is a standard component of the Infrared Spectrometer, Model 12-C, manufactured by the Perkin-Elmer Company of Norwalk, Connecticut. The thermocouple, preamplifier, Model 81 A.C. amplifier, globar, and power supply are also standard Perkin-Elmer equipment. However, because a two-beam technique has been adopted, addition of two mirror boxes and modifications to the chopper assembly have been necessary.

The chopper has been removed from its case and the motor, shutter, and breaker assembly have been mounted in such a position that the two beams will pass the chopper assembly unobstructed. A new shutter has been made with a larger diameter, permitting both beams to be chopped alternately. See Figure 3. The duty cycle of the original shutter is a little less than 180° of rotation. In the present two-beam system, each beam uses a little less than 180° of shaft rotation in each cycle to pass its light signal to the thermocouple detector. The two corresponding amplified signals in each cycle must be separated after detection for independent recording. To accomplish this, a commutator is added to the rear of the breaker shaft of the chopper assembly.

The optical additions to the equipment consist of two mirror boxes, one mounted between the globar and the chopper assembly and the other in front of the monochromator. The two mirror systems are alike in construction. See Figure 4. They consist of two plane first surface mirrors and two curved first surface mirrors each. In the mirror box nearest the source, both plane mirrors view the globar and reflect its image to the curved mirrors. By this means two parallel beams of nearly equal intensity are obtained. The second mirror box receives the two beams on its curved mirrors, bringing them to a focus at the entrance slit of the monochromator.

All these components are mounted on a bridge made of $1\frac{1}{2}$ by 4 inch steel "U" beams welded into a rigid frame. See Figures 1 and 2. On each end of the bridge about 3 feet apart are two tables of 1/4 inch steel plate. The globar, chopper assembly and one mirror are mounted on one table with the power supply underneath. The wattmeter, mounted to the right of the power supply is connected in the globar power line to assist in maintaining constant light intensity. The second mirror box and the monochromator are mounted on the other table with the amplifier below. The two 1/4 inch steel table tops lie in the same plane. The bases of all components mounted on these tables are so designed that precise alignment of the light beams can be made readily.

## II. Alignment of the Optical System

The standard optical alignment procedure of a single beam system is given on the Instructional Manual for the Model 12-C Infrared Spectrometer issued by Perkin-Elmer. That procedure had to be varied because the use of the two beams made the alignment much more critical. Only variations of the procedure recommended by Perkin-Elmer will be discussed here.

First the chopper shutter is phased with the commutator. A Mazda lamp is substituted for the globar. Turning the shutter by hand cam No. 1 is phased so that just as one beam is intersected by the shutter, cam No. 1 closes contact. A three terminal 45 volt battery is used in a continuity test unit, with a switch and Amphenol plugs to fit the proper plugs in the chopper chasis so that different voltages are applied to each cam. See Figure 5. With this test unit plugged in and the chopper running, cam No. 2 can be made 180° out of phase with cam No. 2, by observing the resulting oscilloscope patterns. Following the phasing of cam No. 2 with cam No. 1, the former is switched out of the circuit and cam No. 3 is switched in. By the same procedure as before, cam No. 3 can be made 180° out of phase with cam No. 1. The final adjustmentz are made according to the Perkin-Elmer Instruction Manual.

Assuming that all the components have been mounted on the upper deck of the bridge at approximately the same height, the next step in the optical alignment is to set the globar equidistant from the centers of the two plane mirrors in the first mirror box. See Figure 6. The angle of the plane mirrors is then adjusted so that the images are transmitted to the centers of the curved mirrors. These mirrors in turn are adjusted so that the two images of the globar pass through the exit ports of the box in parallel beams, cross the cloud test region, and enter the second mirror box. The critical adjustments in the first mirror box are those which will make the two beams parallel.

The beams entering the second box first strike the curved mirrors, are reflected to plane mirrors, and are finally directed out of the box into the single entrance slit of the monochromator. The curved mirrors must be rotated until both beams strike the inside edges of their respective plane mirrors. The latter may then be rotated to focus the beams on to the monochromator slit. The monochromator must be oriented and spaced with respect to the second mirror box (and the main axis of the bridge) so that the entrance slit is at the focal point of both curved mirrors. As they enter the slit, the beams are at an angle of about 8 degrees.

The critical adjustments of the optical system are those necessary to satisfy the following requirements:

1. The focal point of the mirrors in the second box must be at the entrance slit.
2. The spacing of mirror box and slit must be such that the diverging beams beyond the entrance slit will fall inside the mask of the monochromator elliptical mirror.
3. The center of the elliptical mirror, the entrance slit, and the inside edges of the second box plane mirrors, which butt together, must have a common center line.
4. The two beams must pass through the entrance slit at equal angles to its axis.

Whenever one of the above parameters is changed, the others must be checked. To determine the focal point of the curved mirror on the slit, the smallest circle of confusion is found at the slit. To determine the position of the focal point of the mirror box optics relative to the slit, the box is moved back and forth, focusing the beams on the slit for each position, until a position is found where both beams make good images on the elliptical mirror and also on the Littrow mirror in the monochromator. To satisfy (3), a string is stretched tightly between the slit and the crack between the plane mirrors; then sighting down the string from the center of the elliptical mirror, the mirror box and monochromator are moved so that they lie in the required line.

The fourth requirement must be met in order that both beams will be focused on the single vacuum thermocouple after passing through the optical system of the monochromator. Both entrance and exit slits are at focal points of the elliptical mirror. If the two beams do not pass the entrance slit at the same small angle, they will not both pass through the exit slit. This condition can be noted only by use of the thermocouple and amplifying system, since the exit light is infrared only. An approximate initial adjustment can be made by suitable changes in the normal position of the Littrow mirror to temporarily obtain visible light at the exit slit. The necessary adjustments are considerably more delicate than indicated in the makers instruction manual, which is concerned only with operation of a single beam system. The aligning procedure is as follows:

1. The whole system is placed in operation. The output of the thermocouple amplifier is observed on an oscilloscope. Du Mont's Model 304-H has been found satisfactory.

2. Oscilloscope displacements, which are proportional to the square root of beam intensity, are observed for each beam and plotted in arbitrary units against slit widths. If the angles of both beams to the slit axes are equal, the plotted curves will coincide. If both sides of the adjustable slits converge on the slit axes at the same rate, the intensity lines will be straight and will pass through the origin of the graph.
3. Numerous readjustments of the many variables must be made to even approximate the ideal form of the intensity/slit width curve.

It is relatively easy to make initial adjustments so that the diverging beams will be transmitted through the prism without cut-off. However, on reflection from the Littrow mirror back to the prism, one of the beams will pass outside the prism if the other is made to fall within the mask of the elliptical mirror. This difficulty is avoided in part by enlarging the mask aperture to the limit on one or both sides. On readjusting the elements, it is then found that a small portion of each beam must be cut out on the second transit of the prism in order that each beam arrive at the thermocouple with equal intensity.

At present an intensity balance has been obtained which is within the tolerances set by other parts of the system. The optical bridge has been mounted beneath the cloud test chamber and refinements of adjustment are in progress.

One trial measurement of water droplet absorption has been made, using a single light beam. The water spray was turned on and off and corresponding infrared beam intensities were measured in succession as rapidly as possible. [illegible] of the data shows that the apparatus indicates expected changes in light intensity with wave length.

The spray nozzles now installed produce a fog of variable drop-size distribution obvious to the observer without instruments. Plans are now being made to stabilize the spray, also to calibrate it by sooted slide or other classical methods. Modifications have been made to a Brown thermocouple potentiometer-recorder to give a continuous and convenient record of beam intensities as observed by the monochromator and amplifiers.

## III. Cloud Test Chamber

The cloud test chamber was built so that an artificial cloud could be made for the testing and calibration of drop size and distribution instruments. The cloud is made by means of a single pneumatic atomizing nozzle, type 1/4 JN with pressure waterfeed, manufactured by the Spraying Systems Company of Bellwood, Illinois.

The chamber is a horizontally mounted cylindrical tank, two feet in diameter and five feet in length. It is made of 16 gauge galvanized iron. The intake end has a removable cover, on which is mounted the spray nozzle and six air jets for mixing. The outlet end is reduced to an exhaust section one foot in diameter and two feet in length. Inside the exhaust section is mounted an electric fan, for clearing the chamber of fog. The chamber, fittings and accessories are shown in Figure 7. On the bottom of the chamber there are three vertical outlet pipes arranged lengthwise and spaced twelve inches apart. To any one of these can be attached the electrostatic drop-size apparatus developed by Dr. R. M. Schotland of this project. There are two horizontal connections on each side of the chamber. One pair connects to a pipe passing through the chamber, the other to the interior of the chamber. These connections are for use with the infrared spectrometer drop distribution measuring equipment under development by Dr. J.C. Johnson. Two additional similar pairs of connections are arranged at 45$^{\circ}$ from the horizontal for use with the visible light scattering meter. The cloud chamber is supported by a frame of two by four inch wooden members which support the tank about five feet above the floor. Beneath the tank is mounted the electrostatic apparatus and its components. The visibility meter and its components are mounted on the cloud chamber frame. The infrared monochromator bridge is just under and on both sides of the cloud chamber. The arrangement of this equipment is illustrated in Figures 1 and 2.

The test chamber has been used but once, in a trial run of the infrared spectrometer. The effectiveness of the chamber in producing clouds of suitable drop-size distribution simulating natural clouds remains to be found by calibration methods now being developed.

## IV. List of Figures

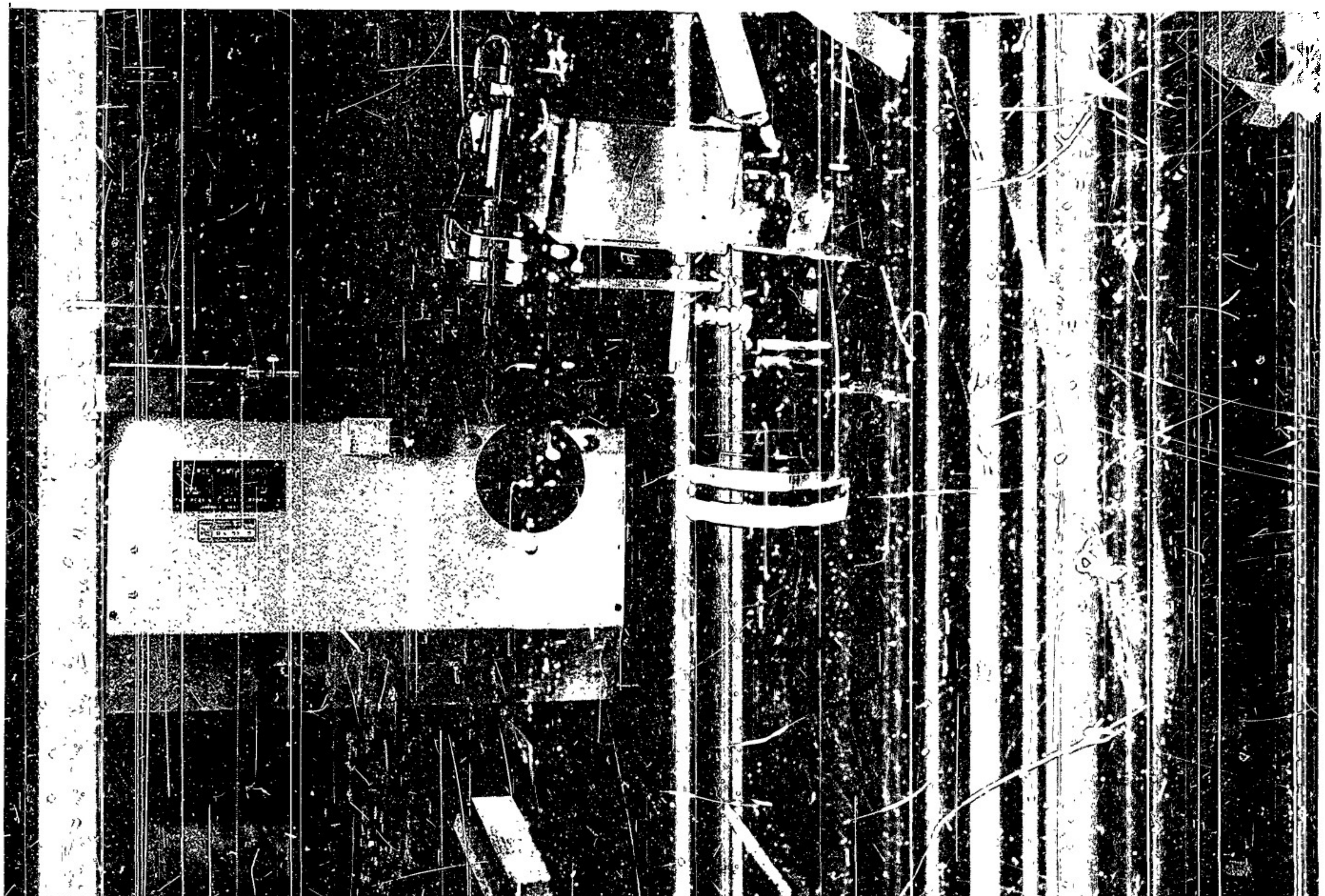
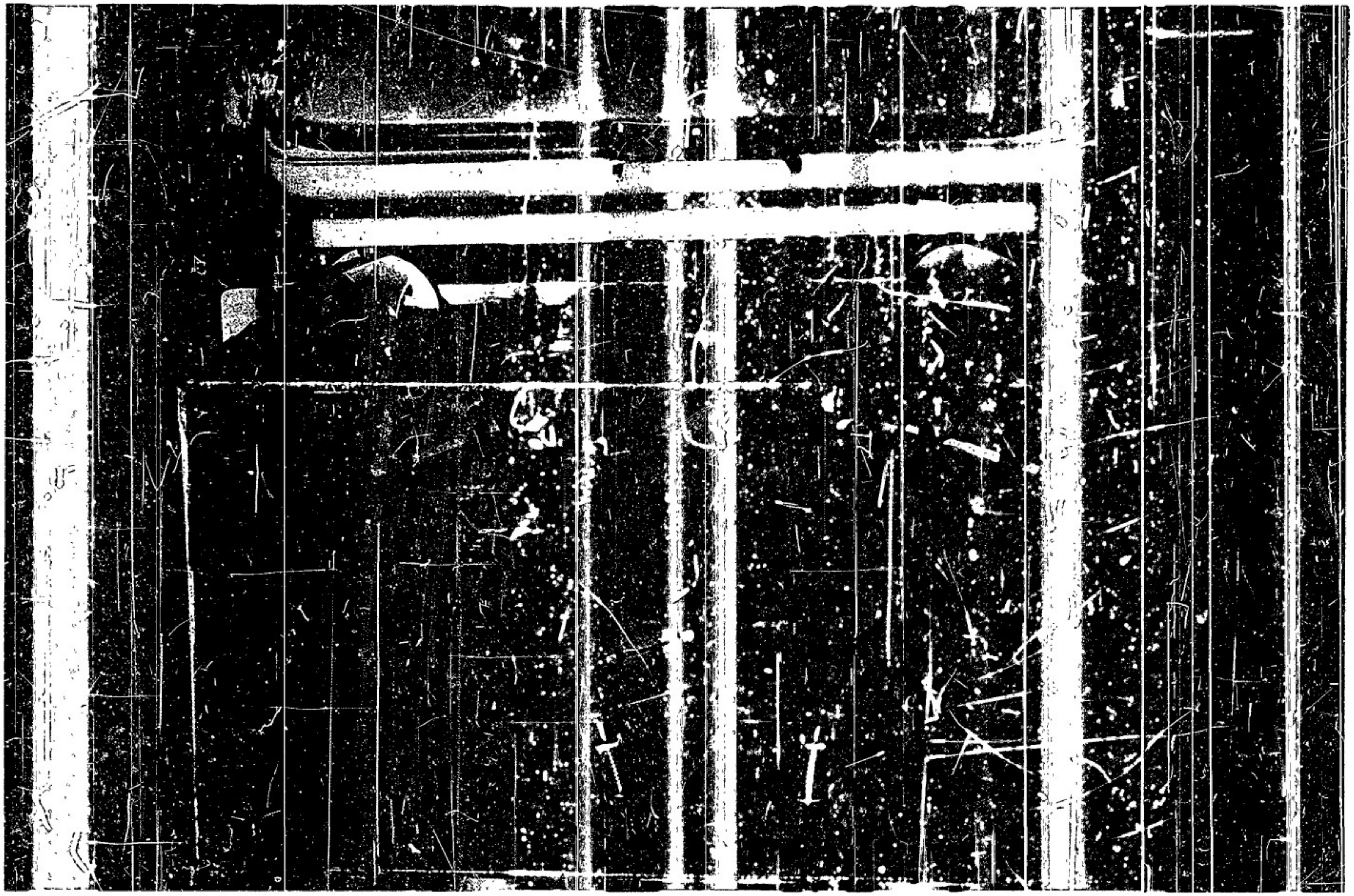


Fig. 1 Infrar[illegible] ce, t[illegible] o[illegible] Ch[illegible]

Fig. 2  Infrar[illegible] [illegible]tor, [illegible]nt of C[illegible]ud Cha[illegible]nber.

Fig. 3 Modified Chopper Assembly.



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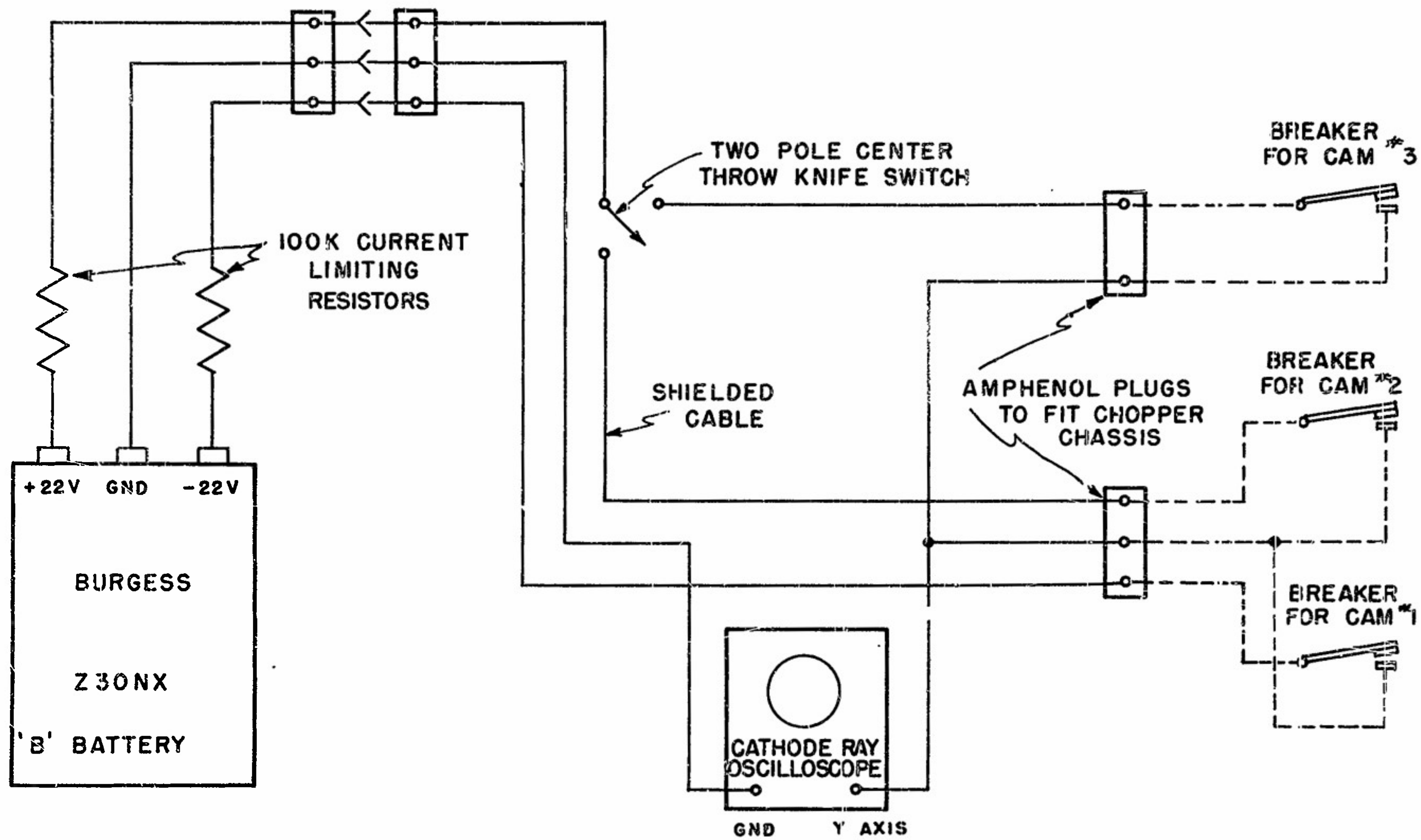


FIG. 5 SCHEMATIC DIAGRAM OF CONTINUITY TEST UNIT

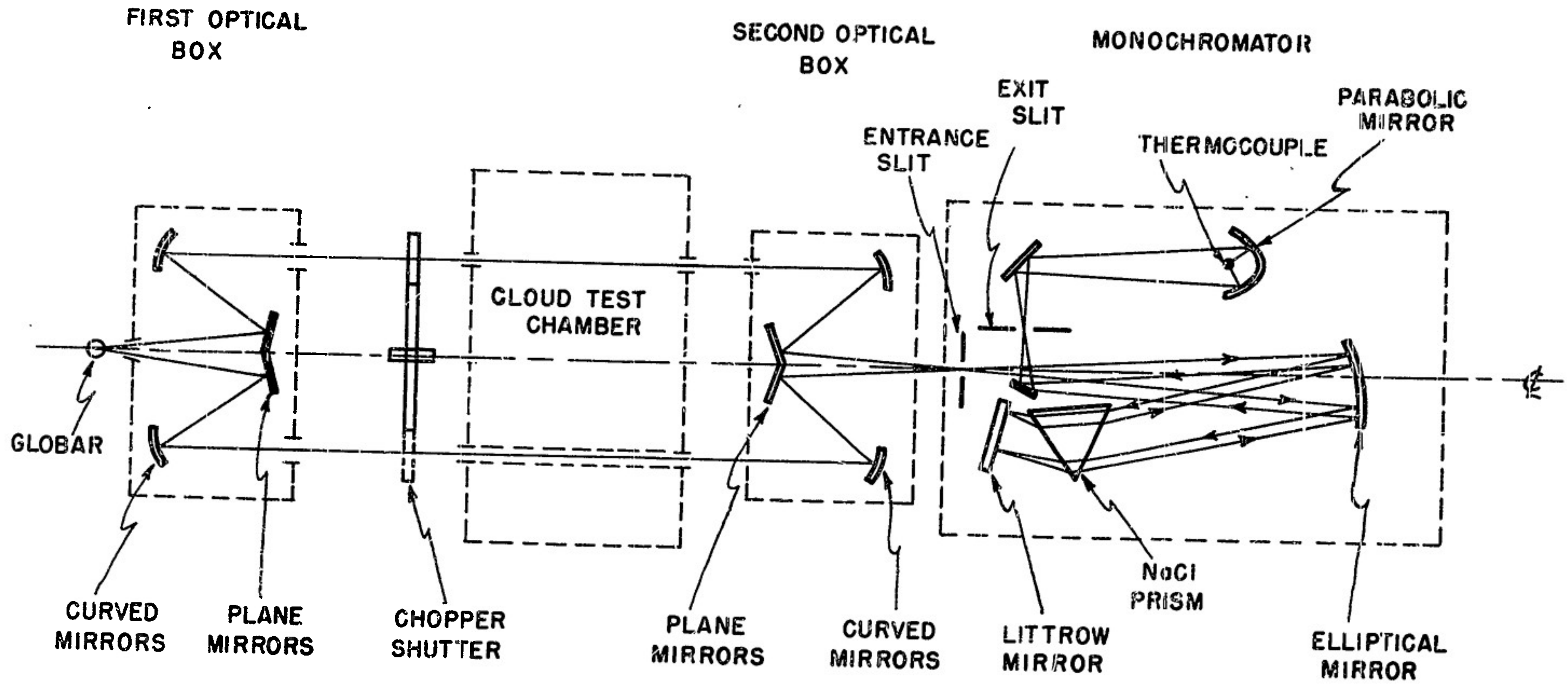


FIG. 6. SCHEMATIC DIAGRAM OF COMPLETE OPTICAL SYSTEM.

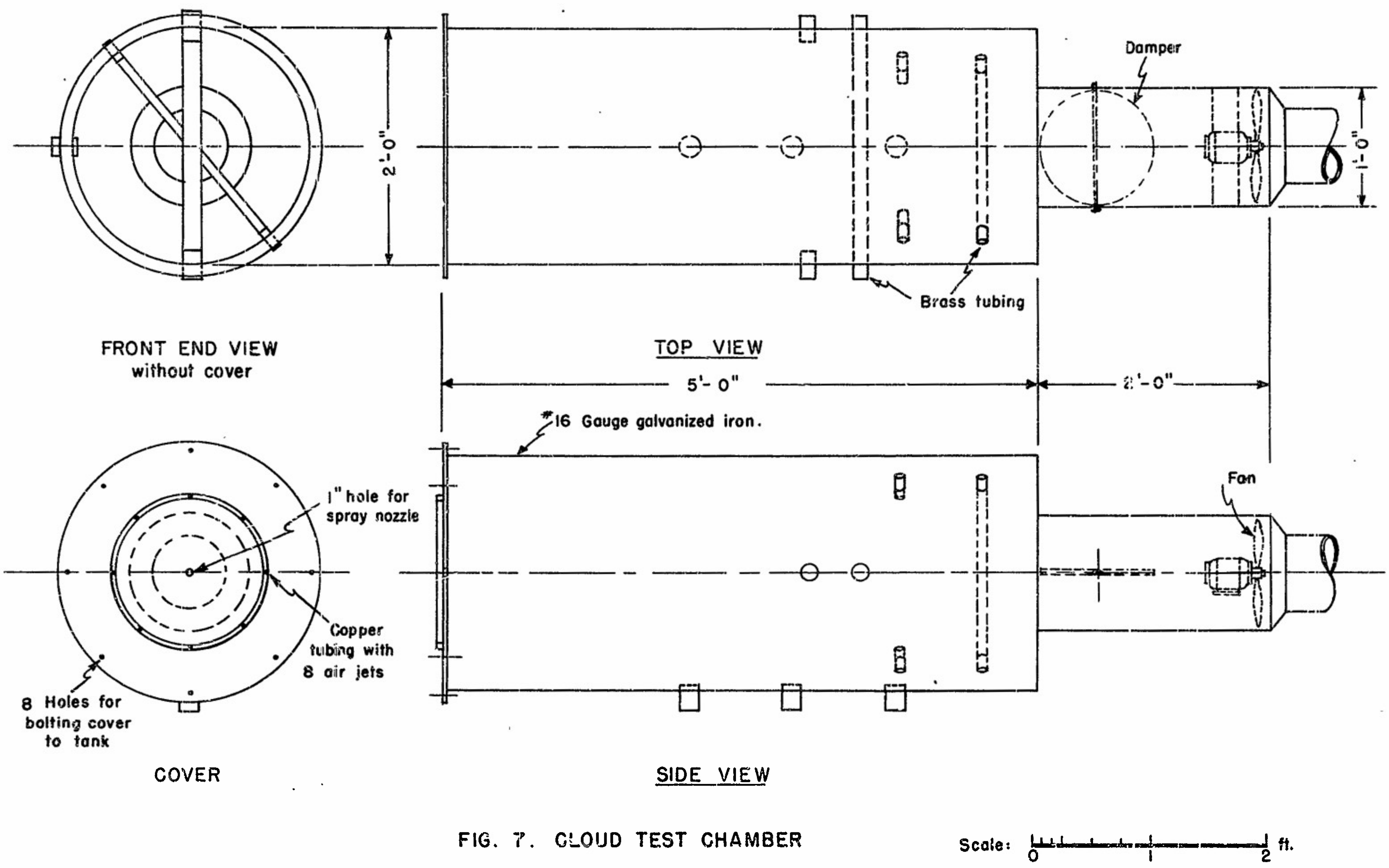


FIG. 7. CLOUD TEST CHAMBER